EVIDENCE FOR TWO DIFFERENT SHOCK INDUCED HIGH-PRESSURE EVENTS AND ALKALI-VAPOR METASOMATISM IN PEACE RIVER AND TENHAM (L6) CHONDRITES; A. El Goresy, B. Wopenka[2], M. Chen[3], S. Weinbruch[4], and T. G. Sharp[5], [1]Max-Planck-Institut für Kernphysik, Postfach 103980, 69029 Heidelberg, Germany; [2]Department of Earth and Planetary Sciences, Washington University, St. Louis, MO 63130, USA; [3]Institute of Geochemistry, Academia Sinica, Guangzhou, China; [4]Fachbereich Materialwissenschaft; Technische Hochschule Darmstadt, Petersenstr .23, 64295 Darmstadt Germany; [5]Bayerisches Geoinstitut, Universität Bayreuth, 95440 Bayreuth, Germany.

Smooth grains in the Peace River shocked matrix previously described as maskelynite are not diaplectic glass but a crystalline phase with a stoichiometric composition (6 cations/10 oxygens). They formed upon decompression by inversion of a parental high-pressure polymorph that crystallized from a dense K-rich melt. They are surrounded by radiating cracks that have extensively shattered the neighboring minerals due to volume increase induced by decompression. Similar grains in Tenham turned out to be glass quenched from a dense alkali-rich melt compositionally unrelated to plagioclase. Expansion of the alkali-bearing aluminosilicate in Peace River and the quenched dense glass in Tenham triggered the second high-pressure event. Neither Peace River nor Tenham contain any maskelynite.

Introduction. Naturally shocked chondrites display a variety of shock features [1-9]. These include intergranular fractures, mosaicism, maskelynite (diaplectic plagioclase glass), planar deformation features (PDFs), and the occurrence of shock melt veins that were found to contain the high-pressure polymorphs ringwoodite, wadsleyite, and majorite [1-9]. These dynamically induced features seem to follow a systematic progressive shock pattern which may allow the construction of a shock classification scheme for shocked chondritic meteorites [1]. The discovery of the assemblage majorite-pyrope$_{ss}$ + magnesiowüstite that crystallized in melt veins in the ixiangkou and other chondrites allowed to constrain the P-T conditions during the crystallization of this particular assemblage [7-9]. The chondritic matrix of such shocked chondrites, which is texturally and petrologically sharply separated from the shock veins, contains grains with plagioclase or plagioclase-like compositions. Optically, those grains are either crystalline (and have PDFs) or, more abundantly, appear to be an amorphous glass and were previously believed to be maskelynite [1,2,6,10]. The sharp transition of veins, where localized melting took place, to a matrix, where presumably solid-state transformations occurred, is not yet understood [1,6]. In addition, the peak pressures estimated for ringwoodite- and majorite-bearing melt veins appear to be grossly overestimated by ~60 GPa [1,6,7-9], and the P-T conditions for the neighboring chondritic matrix are not yet adequately explored either [1,6]. It is e.g. quite puzzling that materials previously described as "maskelynite" are usually smooth with little or no intergranular fractures, while plagioclase grains with PDFs are fractured. What are the P-T conditions and the dynamic processes that on the one hand lead to development of intergranular fractures with PDFs in plagioclase, and on the other hand to solid-state transformation to maskelynite without inducing intergranular fractures during the same shock event? What is the nature of the grains described as "maskelynite" in chondrites? Were they formed by solid-state transformation to amorphous diaplectic glass, or are they melts that were quenched to glass, or are they crystalline phases that were quenched to high-pressure phases from dense melts at high-pressures and later experienced volume increase due to inversion to an a low-pressure polymorph after decompression? In an attempt to adequately address these questions, we have conducted a detailed survey of meteoritic matrices between the melt veins in the Peace River and Tenham (L6) chondrites in which "maskelynite" was previously reported [2,6,10].

Analytical techniques. Plagioclase and maskelynite-like grains were investigated in polished thin sections (PTS) using the following techniques: transmitted and reflected-light microscopy, BSE techniques in SEM and field emission SEM (FESEM), electron probe microanalysis (EMPA), laser Raman microprobe (LRM) spectroscopy of individual and selected areas of grains, high resolution electron microscopy (HRTEM), and analytical electron microscopy (ATEM). The areas of interest were cored out for HRTEM and ATEM using a high precision microdrill.

Results: Peace River: We notice gradual but distinct spatial textural and compositional changes of plagioclase and material that optically looks like maskelynite from the vicinity of the shock melt veins into the meteoritic matrix. Grains adjacent to the veins are smooth with no intergranular fractures. They are always surrounded by numerous radiating cracks that have extensively shattered the neighboring silicates, chromite, and troilite. The radiating cracks are indicative of volume increase due to expansion of the grains that optically look like maskelynite. With increasing distance from the veins, the grains are not fully smooth but contain cracked islands with the cracks terminating within the "maskelynite" at the contact to the smooth regions. More than 400 mm away from the melt veins grains that optically look like maskelynite does not exist any more, but only plagioclase with intergranular fractures that continue in the neighboring silicates, chromite, and troilite. Those plagioclase grains do not display any radiating expansion cracks. A systematic EMPA survey of both the "maskelynite" and plagioclase grains in the meteoritic matrix revealed distinct systematic differences in their chemical compositions: **a)** None of the smooth regions that optically looks like maskelynite have a stoichiometric plagioclase composition, and the compositions also differ from that of the crystalline plagioclase grains. The smooth grains and regions are highly enriched in K_2O in comparison to the fractured plagioclase (up to 3.6 wt% vs. 0.8 wt% K_2O), and have a cation/anion ratio of 6/10 [$(NaKCaFe)_{0.973}(Al\ Si)_{5.08}O_{10}$]. LRM investigations showed that these grains are not amorphous glass (and thus definitely are not maskelynite, as previously reported), but rather a mineral that has the structure of tetrahedrally coordinated silicon such as is the case in olivine. The grains display two strong Raman peaks at 828 and 856 cm^{-1}, and small peaks at 668, 924, and 954 cm^{-1}.

Based on these Raman results, those smooth grains, which compositionally differ from plagioclase, must represent a new mineral (that we call "Phase B"). It probably formed upon decompression by inversion of a parental high-pressure polymorph, that crystallized from a dense K-rich melt. **b)** Potassium X-ray maps of grains with cracked islands (up to 200 mm away from shock veins) revealed that the islands consist of PDF-rich plagioclase fragments that are disorderly distributed in the K-rich smooth matrix. PDF lamellae in these fragments are also enriched in K. Hence, we argue that the PDFs were also molten under pressure and were subsequently enriched in K. HRTEM confirmed that the fractured islands to be plagioclase with PDFs. LRM spectra of the cracked islands in the smooth regions show peaks that are typical for plagioclase (173, 285, 411, 482 and 512 cm^{-1}) and also peaks characteristic of Phase B. **c)** Crystalline plagioclase grains >400 mm away from the veins yield normal plagioclase Raman spectra without any additional peaks. The shock melt veins are the potential source for the K enrichment in the chondritic matrix. Potassium (and some Na) evaporated from the melt veins during the shock event, probably flushed the matrix through shock induced intergranular fractures and were locally trapped in the melt pockets with plagioclase composition. In fact the K X-ray maps disclosed discrete K-rich grains attached to the walls of the intergranular fractures which connect the melt veins with the chondritic matrix. EMPA broad beam analysis of shock melt veins revealed that K is below delectability (<0.01 wt% K_2O). The Na_2O-content of the veins (0.70 wt%) is also considerably lower than in the Peace River bulk (1.19 wt%). Thus all K and about half of Na were evaporated from the shock melt veins during the shock event. The reason that sodium was not entirely lost to the vapor phase is that considerable amounts were incorporated in the majorite-pyrope$_{SS}$ (5.1 mole % Na-majorite) on the onset of garnet crystallization [9].

Tenham: We find very similar textural relations in the Tenham chondritic matrix: **a)**. A smooth material with the optical appearance of maskelynite but compositions not matching plagioclase. They are surrounded by pervasive radiating cracks that shattered the neighboring minerals. In fact the radiating cracks outnumber the shock induced intergranular fractures. **b).** Cracked plagioclase islands with PDFs within material that optically resembles maskelynite. **c)** No plagioclase with intergranular fractures was encountered in the Tenham PTS **d)** FESEM revealed that the smooth areas and the PDF lamellae in the cracked plagioclase islands preferentially are enriched in Na. LRM investigations indicate that the cracked islands with PDFs are crystalline plagioclase. **e)** The smooth grains in Tenham are not as enriched in K as their counterparts in Peace River (1.08 wt% vs. 3.6 wt% K_2O). However, the Na_2O content vary dramatically within individual smooth areas (2.41 to 9.00 wt% Na_2O), so that none of the smooth grains has a stoichiometric plagioclase composition. The smooth grains do not show any indication for the presence of Phase B, but instead the Raman spectra display unstructured humps for amorphous glass, and show strong resemblance to the Raman spectra of material in Shergotty that optically resembles maskelynite.

Discussion: We did not find a single grain with maskelynite-like appearance that have plagioclase composition in any of the 4 PTS of Peace River and the 2 PTS of Tenham that we carefully analyzed. Smooth grains previously reported in Tenham to be maskelynite [2,6,10] are Na- and K-rich glasses compositionally unrelated to plagioclase. Our findings indicate that they are glasses that were quenched at high-pressure from melts that are compositionally distinct from maskelynite or plagioclase. In comparison, similar material in Peace River is a crystalline K-rich aluminosilicate with an orthosilicate-related sructure. This mineral is stoichiometric (6 cations/10 oxygens). We conclude, that the material in Tenham and Peace River that previously was thought to be maskelynite did not form by solid-state transformation to diaplectic glass [2,6,10], but rather by local melting of plagioclase, followed by Na and K metasomatism causing the enrichment of the mineral melts in the alkalis. Both Na and K originated from the melt veins through shock-induced evaporation. Na was not entirely lost from the melt veins since it was in part incorporated in the majorite-pyrope$_{ss}$ that appeared as the liquidus phase at high pressures and temperatures [7-9]. We anticipate that the amount of the Na lost from the veins was controlled by the difference between the peak temperature and the liquidus temperature of the majorite-pyrope$_{SS}$ assemblage. After garnet crystallization, no more Na was lost from the veins. Since K is not incorporated in any of the liquidus phases in the melt veins, it was entirely lost to the vapor phase and subsequently scavenged by the plagioclase and PDF melts. The presence of the pervasive radiating cracks around the smooth material that optically looks like maskelynite in Peace River and Tenham indicates that the grains must have experienced considerable volume increase due to expansion. The expansion, evidently induced a second high-pressure event, with a magnitude (presumably few GPas) lower than the shock induced peak pressures, caused the pervasive fracturing of the meteorite matrices. This second high-pressure event must have taken place after solidification of the alkali-rich melt under high-pressures since **a)** We find no alkali-rich offshoots in the radiating expansion cracks, **b)** Smooth grains adjacent to the shock melt veins induced radiating cracks that penetrated and shattered the garnet-magnesiowüstite intergrowth in these veins, **c)** Metal-troilite blebs in the veins do not display any offshoots in these radiating cracks. We hence estimate that the second event took place at T below the Fe-FeS eutectic (<980°C). Our results call for a careful and detailed scrutiny of shocked chondritic meteorites in which maskelynite was previously reported [1].

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